Caltrans Metric

APRIL 1998

Structural Detailing Standards

Table of Contents

Structural Detailing Standards

1. General

Guidelines

Items not covered by References 2 and 3 should be "soft" converted. This is an exact restating of the English units in metric units. (Ref. 4) (See last page for list of references.)

Other items needed to allow for metric design to occur should be sent to Jerry Champa, Caltrans Metric Coordinator in the Office of Planning and Design (Ref. 4), or the chairperson of the structure technical committee that covers that subject.

Headquarters Office of Office Engineer (OE) has converted the Standard Specifications, Standard Plans, Standard Special Provisions and the BEES (Basic Engineering Estimating System) and issued them in July 1995. (Ref. 4)

2. Paper Sizes (Ref. 1)

Metric drawings may be made on any size paper. We will continue to use the old 24" x 36" paper until new metric paper is available, or is required.

The ISO "A" series sizes are preferred metric sizes for design drawings. There are five "A" series sizes:

- A0 1189 × 841 mm (46.8 × 33.1 inches)
- A1 841 × 594 mm (33.1 × 23.4 inches)
- A2 594 × 420 mm (23.4 × 16.5 inches)
- A3 420 × 297 mm (16.5 × 11.7 inches)
- A4 297 × 210 mm (11.7 × 8.3 inches)

A0 is the base drawing size with an area of one square meter. Smaller sizes are obtained by halving the long dimension of the previous size. All A0 sizes have a height to width ratio of one to the square root of 2.

3. Drawing Sizes (Ref. 1)

Structures currently uses 24" × 36" paper with a 21" × 33½"± drawing size. This is consistent with "A1" which means no changes in drawing size are required. It would appear that our method of 50% reductions for reduced sets is also consistent with the new guidelines.

4. Scales

Metric drawing scales are expressed in nondimensional ratios.

The following scales are proposed by ESC, Office of Engineering Technology, CADD Services.

Metric Scales	Close Imperial Scales
1:1 (Full Size)	1' = 1' (Full Size)
1:2 (Half Size)	6" = 1'-0" (Half Size)
1:2.5	3" = 1'-0"
1:5	1-½" = 1'-0"
1:10	1" = 1'-0"
1:20	¾" = 1'-0"
1:25	½" = 1'-0"
1:40	⅜" = 1'-0"
1:50	¼" = 1'-0"
1:80	3⁄16" = 1'-0"
1:100	1⁄10" = 1'-0"
1:125	3⁄32" = 1'-0"
1:200	1⁄16" = 1'-0"
1:250	1" = 20'
1:400	1" = 30'
1:500	1" = 40'
1:1000	1" = 80'
1:2000	1" = 200'
1:5000	1" = 500'
1:10000	1" = 1000'

Headquarters is proposing the following for **Profile Sheets** (Ref. 2)

1. Rural Sections in hilly or mountainous terrain – 1:100 vertical, 1:1000 horizontal
2. Rural or urban with gentle rolling terrain – 1:50 vertical, 1:500 horizontal
3. Rural or urban with level terrain – 1:20 vertical, 1:200 horizontal

Headquarters is proposing the following for **Cross Sections** (Ref. 2):

1. Rural – 1:100
2. Urban – 1:50

5. Units

Dual units shall not be allowed on the plans with the exception of Right-of-Way data as described above. (Ref. 2)

Plans will contain metric units only, not metric and English.

The preferred metric unit is the millimeter. All dimensions on bridge and building drawings shall be "mm" exclusively as recommended in the General Services Administration, Office of Design and Construction "Metric Design Guide." This is also consistent with the AASHTO Metric LRFD manual which uses "mm" for all dimensions in formulas, legends, notes, and comments. Use of mm for all dimensions is how dimensions are specified in major codes, leads to integers for all bridge dimensions and eliminates use of decimal points.

The only exception is for surveying data, site plans, foundation plans and log of borings.

Do not use unit symbols but provide an explanatory note on each sheet:

"All dimensions are shown in millimeters, except as noted."

or

"All dimensions are shown in meters, except as noted."

6. Writing Conventions (Ref. 5)

Use upright text

Correct: Bob is running in tomorrow's **10 km** race.

Incorrect: Bob is running in tomorrow's ***10 km*** race.

Plural Same as Singular

Correct: To train for the **10 km** race, Bob runs 2 km a day.

Incorrect: To train for the **10 kms** race, Bob runs 1 km a day.

No Period Follows (except end of sentence)

Correct: After the **10 km** race, Bob will walk 1 km.

Incorrect: After the **10 km.** race, Bob will walk 1 km.

Use Lower-Case (except for abbreviations derived from someone's name):

Unit	Abbreviate as:	Unit	Abbreviate as:
centimeter	cm	liter	L *
millimeter	mm	Celsius	°C
kilometer	km	newton	N
kilogram	kg	joule	J

*The symbol "L" is recommended for liter in the United States since the lower-case letter "l" can easily be confused for the numeral 1 although both the upper-case "L" and the lower-case "l" are approved alternative symbols.

Space Between Digit Number and Unit Symbol

Correct: 35 mm or 250 kg
Incorrect: 35mm or 250kg
Exceptions: 45° and not 45 ° or 20°C and not 20° C

No Space between Prefix or its Symbol and Unit

Correct:	megapascal	MPa
Incorrect:	mega pascal	M Pa

With Symbols

Use Raised Dot for Product:

Example: N·m for newton meter

- with typewriter, use period (N.m)

Use Slash or Solidus for Quotient:

Example: meters per second: use **m/s** or $\mathbf{m \cdot s^{-1}}$ or $\frac{\mathbf{m}}{\mathbf{s}}$

With Unit Names

Use Space or Hyphen for Product:

Correct: newton meter, or newton-meter
Incorrect: newtonmeter
Exception: watthour

Use "per" for Quotient (not /):

Correct: meter per second
Incorrect: meter/second

Group Digits by Three from Decimal Point. No Comma Within a Number

U.S.	International (metric)
26,345	26 345
2.141596	2.141 596

In numbers with FOUR digits on either side of the decimal a space is not necessary for uniformity in tables.

Correct: 0.1335 kg or 2345 kg
Incorrect: 0.133 5 kg or 2 345 kg

Fractions Unnecessary

Correct: 2.5 m
Incorrect: 2½ m

Use Zero before Decimal Marker

Correct: 0.1234
Incorrect: .1234

7. Metric Conversions

Whole numbers always indicate millimeters. Decimal numbers taken to three places always indicate meters. For example, 90.365 is 90 meters and 365 millimeters.

Significant digits should be specified to the nearest millimeter modules consistent with the accuracy necessary for construction. For bridge design, CIP concrete dimensions should be specified to the nearest 5 mm (approximately 3⁄16 inch).

Common Conversion Factors to Metric Units

Class	Multiply:	By:	To Get:
Area	acre	4047.0	m^2
	acre	0.4047	ha(10,000 m^2)
	ft^2	0.0929	m^2
	yd^2	0.8361	m^2
	mi^2	2.590	km^2
Length	ft	0.3048 *	m
	in	25.4 *	mm
	mi	1.6093	km
	yd	0.9144 *	m
Volume	ft^3	0.0283	m^3
	gal	3.785	L **
	fl oz	29.574	mL **
	yd^3	0.7646	m^3
	acre ft	1233.49	m^3
Mass	oz	28.35	g
	lb	0.4536	kg
	kip (1,000 lb)	0.4536	tonne (1000 kg)
	short ton (2,000 lb)	907.2	kg
	short ton	0.9072	tonne (1000 kg)
Force	lb	4.448 22	N
	kip	4.448 22	kN
Density	lb/yd^3	0.5933	kg/m^3
	lb/ft^3	16.0185	kg/m^3
Pressure	psi	6894.7	Pa
	ksi	6.8947	$MPa(N/mm^2)$
	lb/ft^2	47.88	Pa
Velocity	ft/s	0.3048 *	m/s
	mi/h	0.4470	m/s
	mi/h	1.6093	km/h
Light	footcandle (lumen/ft^2)	10.764	lux(lx) (lumen/m^2)
Temperature	°F	$(t_{°C} = t_{°F} - 32)/1.8$	°C

*Exact

**Both the upper-case “L” and lower-case “l” may be used for liter. However, “L” is preferred so as not to be confused with the numeral “1”.

8. Concrete Strength

Concrete f_c'	Soft	Use
3,600 psi	24.82 MPa	25 MPa
4,000 psi	27.58 MPa	28 MPa
5,000 psi	34.47 MPa	35 MPa
6,000 psi	41.37 MPa	42 MPa *

*Specify concrete strengths in 7 MPa increments above 28 MPa.

Note: The standard design strength has been changed from 3,250 psi to 28 MPa (4,000 psi).

9. Reinforcement

Metric reinforcement will be used in place of Imperial.

Metric Reinforcing Bars: Use ASTM A615M Grade 420 or ASTM A706M Grade 420

Bar Sizes – Inch-Pound and Soft Metric[A]

Bar Designation No.		Nominal Diameter		Nominal Area	
Imperial	**Metric**	**in.**	**mm**	**in.²**	**mm²**
3	10	0.375	9.5	0.11	71
4	13	0.500	12.7	0.20	129
5	16	0.625	15.9	0.31	199
6	19	0.750	19.1	0.44	284
7	22	0.875	22.2	0.60	387
8	25	1.000	25.4	0.79	510
9	29	1.128	28.7	1.00	645
10	32	1.270	32.3	1.27	819
11	36	1.410	35.8	1.56	1006
14	43	1.693	43.0	2.25	1452
18	57	2.257	57.3	4.00	2581

[A] Bar designation numbers approximate the number of millimeters of the nominal diameter of the bar.

Note: Do not use "M" in calling out reinforcement on the plans (example: #36 @ 250). Do not use "mm" for spacing unless in a note.

Specify bar lengths to the nearest 10 mm for embedment and hook dimensions, and 50 mm for lengths.

Spacing of reinforcement should be shown to the nearest 25 mm.

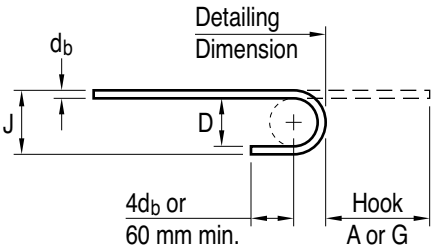
Standard Metric Hook details are available on next page.

Standard Metric Hook Details
In accordance with ACI 318M-89

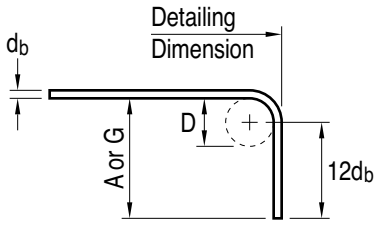
NOTE: All dimensions are in millimeters [mm]

All Grades: D = finished inside bend diameter
d_b = nominal bar diameter

D = $6d_b$ for #10 through #25
D = $8d_b$ for #29, #32 and #36
D = $10d_b$ for #43 and #57



180°



90°

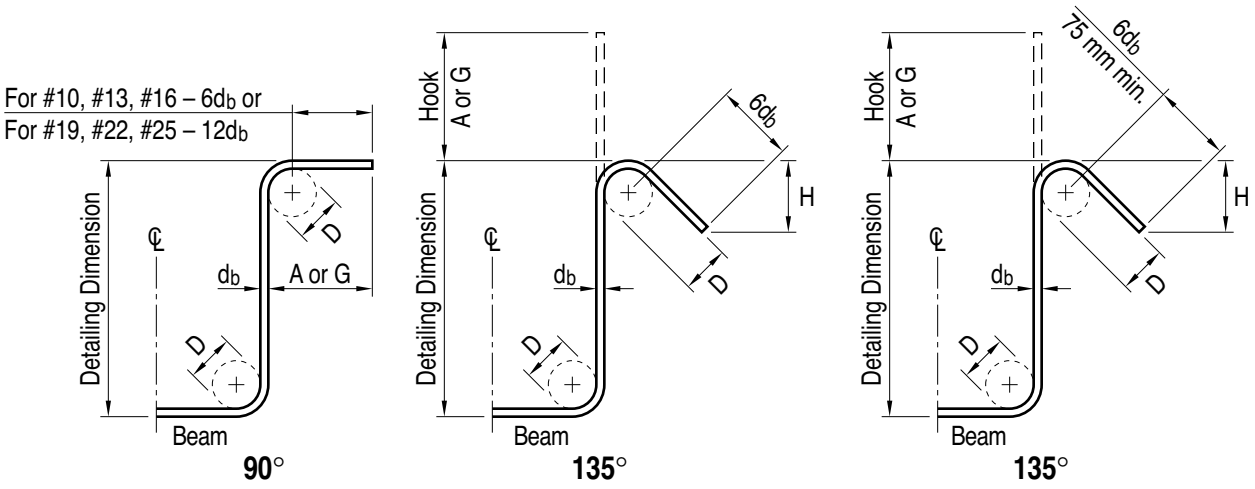
Recommended End Hooks, All Grades

Bar Size	D	180° Hooks		90° Hooks
		A or G	J	A or G
#10	60	125	80	150
#13	80	150	105	200
#16	95	175	130	250
#19	115	200	155	300
#22	135	250	180	375
#25	155	275	205	425
#29	240	375	300	475
#32	275	425	335	550
#36	305	475	375	600
#43	465	675	550	775
#57	610	925	725	1050

Standard Metric Hook Details (continued)
In accordance with ACI 318M-89

NOTE: All dimensions are in millimeters [mm]

D = bend diameter



Stirrup Hooks (Tie Bends Similar)

Seismic Stirrup/Tie

Stirrup Hooks (Tie Bends Similar)

Bar Size	D	90° Hooks	135° Hooks	
		A or G	A or G	H
#10	40	105	105	65
#13	50	115	115	80
#16	65	155	140	95
#19	115	305	205	115
#22	135	355	230	135
#25	155	410	270	155

Seismic Stirrup/Tie

Bar Size	135° Seismic Hooks		
	D	A or G	H
#10	40	110	80
#13	50	115	80
#16	65	140	95
#19	115	205	115
#22	135	230	135
#25	155	270	155

"D" dimension is bend diameter.
"H" dimension is approximate.

Table 2. Comparison of Deformed Bar Designation Numbers, Nominal Weights [Masses], Nominal Dimensions, and Deformation Requirements

Bar Designation No. [A]	Nominal Weight, lb/ft [Nominal Mass, kg/m]	Nominal Dimensions[B]			Deformation Requirements, in. [mm]		
		Diameter, in. [mm]	Cross-Sectional Area, in.^{2} [mm^2]	Perimeter, in. [mm]	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12.5% of Nominal Perimeter)
3 [10]	0.376 [0.560]	0.375 [9.5]	0.11 [71]	1.178 [29.9]	0.262 [6.7]	0.015 [0.38]	0.143 [3.6]
4 [13]	0.668 [0.994]	0.500 [12.7]	0.20 [129]	1.571 [39.9]	0.350 [8.9]	0.020 [0.51]	0.191 [4.9]
5 [16]	1.043 [1.552]	0.625 [15.9]	0.31 [199]	1.963 [49.9]	0.437 [11.1]	0.028 [0.71]	0.239 [6.1]
6 [19]	1.502 [2.235]	0.750 [19.1]	0.44 [284]	2.356 [59.8]	0.525 [13.3]	0.038 [0.97]	0.286 [7.3]
7 [22]	2.044 [3.042]	0.875 [22.2]	0.60 [387]	2.749 [69.8]	0.612 [15.5]	0.044 [1.12]	0.334 [8.5]
8 [25]	2.670 [3.973]	1.000 [25.4]	0.79 [510]	3.142 [79.8]	0.700 [17.8]	0.050 [1.27]	0.383 [9.7]
9 [29]	3.400 [5.060]	1.128 [28.7]	1.00 [645]	3.544 [90.0]	0.790 [20.1]	0.056 [1.42]	0.431 [10.9]
10 [32]	4.303 [6.404]	1.270 [32.3]	1.27 [819]	3.990 [101.3]	0.889 [22.6]	0.064 [1.63]	0.487 [12.4]
11 [36]	5.313 [7.907]	1.410 [35.8]	1.56 [1006]	4.430 [112.5]	0.987 [25.1]	0.071 [1.80]	0.540 [13.7]
14 [43]	7.65 [11.38]	1.693 [43.0]	2.25 [1452]	5.32 [135.1]	1.185 [30.1]	0.085 [2.16]	0.648 [16.5]
18 [57]	13.60 [20.24]	2.257 [57.3]	4.00 [2581]	7.09 [180.1]	1.58 [40.1]	0.102 [2.59]	0.864 [21.9]

[A] Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars [bar numbers approximate the number of millimeters of the nominal diameter of the bar].

[B] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight [mass] per foot [meter] as the deformed bar.

General Method for Handling Rebar Shown on the Plans

The specifications will require the contractor to substitute the soft converted metric rebar sizes (ASTM Designation: A 706/A 706M - 96a and A 615/A 615M) whenever hard converted metric rebar sizes are shown on the plans or specified. The specs will also allow substituting imperial bar sizes for soft converted metric rebar sizes. In general:

- If the bar reinforcement shown on the plans or specified has a metric bar designation number shown in Column A in Table 1 below, reinforcement conforming to the corresponding bars in Column B **must** be substituted.
- At the contractor's option, reinforcement with an imperial bar designation number as shown in Column D in Table 2 below, may be substituted for bars corresponding to metric designation number shown in Column C. This would include bars shown on the plans or specified that have a metric bar designation shown in Column C or bars that are to be substituted as shown in Table 1.

Table 1

Column A	Column B
Metric Bar Designation Number	**Metric Bar Designation Number**
10	13
15	16
20	19
–	22
25	25
–	29
30	32
35	36
45	43
55	57

Table 2

Column C	Column D
Metric Bar Designation Number	**Imperial Bar Designation Number**
13	4
16	5
19	6
22	7
25	8
29	9
32	10
36	11
43	14
57	18

Note: This change will eliminate the #3 imperial bar size and replace it with the #4 bar size until July 1997 metric Standard Plans are issued.

10. Structural Steel

Structural member sizes will be "soft" converted in accordance with ASTM AGM. In the future LRFD specifications will use nondimensional property factors.

11. Survey information (Ref. 2)

All survey information will be expressed in meters except property data. Only property data shall be expressed in dual units with the primary expression being the units which are recorded in County records. (Ref. 2)

Caltrans has adopted 100 meters per station. There will be a tick mark at 20 m intervals. Elevations are to be expressed in meters, probably to the nearest mm. For example:

- Elevation 100.040 (meters)
- Station 80+12.320
  80 (100 meters/station = 8000 meters from source)
  12 (meters)
  320 (mm)

Map grid ticks shall be every 200-250 mm depending on scale. Crosshair legs shall be 20 mm long (actual plan dimension).

Angular measurement will retain degree-minute-second convention. (Ref. 2)

12. Cross Slopes (Ref. 2)

Pavement cross slope and superelevation shall be shown as a percent.

13. Side Slopes (Ref. 8)

- Slope is expressed in nondimensional ratios. The vertical component is shown first and then the horizontal. For instance, a rise of one meter in four meters is expressed as 1:4. The units that are compared should be the same (meters to meters, millimeters to millimeters).
- For slopes less than 45°, the vertical component should be unitary (for example, 1:20). For slopes over 45°, the horizontal component should be unitary (for example, 5:1).

14. Cross Section Intervals (Ref. 2)

Caltrans has adopted 20 m. (Ref. 2) They may reduce this.

15. Contour Intervals (Ref. 2)

Headquarters is proposing the following. (Ref. 2)

Scale	Index Contours	Intermediate Contours
1:200	1 m	0.25 m
1:500	2 m	0.5 m
1:1000	5 m	1 m
1:2000	10 m	2 m
1:5000	25 m	5 m

This seems adequate for our work, except as follows: For bridge deck contours, use 0.1 m or 0.05 m intervals as needed.

16. Footings

Specify allowable pressures to the nearest kPa.

Multiply psf × 0.047 88 to get kPa.

Example:

Pressure	Soft	Proposed
3,000 psf	143.6 kPa	145 kPa
4,000 psf	191.5 kPa	190 kPa

17. Piles

Specify pile diameters to the nearest 5 mm, or 10 mm

Example:

Pile Diameter	Soft	Proposed
12"	304.8 mm	305 mm
16"	406.4 mm	405 mm
18"	457.2 mm	460 mm

Specify pile spacing to the nearest 100 mm.

Example:

Pile Spacing	Soft	Proposed
1'-6"	457.2 mm	500 mm
3'-0"	914.4 mm	900 mm

Specify pile capacity to the nearest 25 kN. Multiply tons × 8.89644 to get kN.

Example:

Pile Capacity	Soft	Proposed
45 ton	400.3 kN	400 kN
70 ton	622.8 kN	625 kN

Specify tip to nearest 0.05 m.

18. Bolts

ASTM Spec. A325M and A490M:

Standard Bolt and Hole Diameter (Ref. 7)

AISC/LFRD (ASTM A325 - A490)				ISO/TC167 (ASTM A325M - A490M)	
Bolt Diameter		Hole		Bolt Diameter	Hole
inches	mm "soft"	inches	mm "soft"	mm "hard"	mm "hard"
½	12.7	9/16	14.3	–	–
5/8	15.9	11/16	17.5	M16	18
¾	19.0	13/16	20.6	–	–
–	–	–	–	M20	22
7/8	22.2	15/16	23.8	M22	24
–	–	–	–	M24	26
1	25.4	1-1/16	27.0	–	–
1-1/8	28.6	1-3/16	30.2	M27	30
1-¼	31.8	1-5/16	33.3	M30	33
1-3/8	34.9	1-7/16	36.5	–	–
–	–	–	–	M36	39
1-½	38.1	1-9/16	39.7	–	–

"soft" metric bolt/hole sizes: exact conversion from SI units.

"hard" metric bolt/hole* sizes: adjustment to metric sizes.

* **"hard"** conversion means more than adjusting to metric hole sizes. We also adjust tolerances for larger bolt sizes.

Recommendation (Ref. 7):

Depending on the size of the project and anticipated construction dates, the designer should carefully look at several options when selecting bolt diameters and whether to use **"hard"** or **"soft"** metric bolt sizes. In the interim, it may be prudent for the designer to show optional connections using either **"hard"** or **"soft"** metric bolts sizes giving appropriate consideration to such issues as **net section requirements**. The use of the M22.2 (7/8" diameter) versus the M22 bolts represents a good solution to the issue where the "hard" and "soft" metric bolts would be interchangeable without significant problems.

Suggested Permissible Bolt Substitutions (Ref. 7)

Metric Bolt (mm)	U.S. Substitution (inches)
M16	⅝
M22	⅞
M27	1-⅛
M30	1-¼

Commentary (Ref. 7):

M20, M22, and M24 bolts should be available from several manufacturers. The manufacturers will probably not build up an inventory of sizes, so delivery schedule may be a problem, at least for the near term. Production of larger bolts such as M27 and M30 is not anticipated until the demand justifies the investment in tooling.

19. Bearing Pads and Joint Seal Assemblies

Steel reinforced bearing pads are vulcanized in a mold, so a "soft" conversion will be required at first. There should be no problem with fabric pads, dimension to the nearest 50 mm. Pad thickness should be determined in 12.5 mm increments.

Joint Seal Assemblies will be "soft" converted.

The following movement rating categories will be used.

MR (mm)	Type of Seal
15	Type A
30 - 50	Type B
60 - 100	Joint Seal Assembly (stripseal)
> 100	Joint Seal Assembly (modular)

Movement ratings shall be rounded to the nearest 10 mm, except Type "A" seals.

20. Prestressed Concrete

Current 0.6" and 0.5" strand are used worldwide and will be “soft” converted.

P/S notes to metric: Round P_{jack} to nearest 50 kN.
Anchor set “soft” convert.

21. Vertical Clearance

- 5.1 m (16.73') replaces 16.5'
- 4.9 m (16.07') replaces 16.0'
- 4.6 m (15.09') replaces 15.0'
- 4.5 m (14.76') replaces 14.5'

22. Examples of Notes

GENERAL NOTES
LOAD FACTOR DESIGN

DESIGN:	BRIDGE DESIGN SPECIFICATIONS (1992 Fifteenth Edition AASHTO with Interims and Revisions by CALTRANS)
DEAD LOAD:	Includes 1675 Pa for future wearing surface.
LIVE LOADING:	HS20-44 and alternative and permit design load.
SEISMIC LOADING:	Peak Rock Acceleration = 0.6 g Depth of Alluvium < 3 m
REINFORCED CONCRETE:	f_y = 414 MPa f_c' = 28 MPa n = 8
PRESTRESSED CONCRETE:	See “Prestressing Notes”

PRESTRESSING NOTES

1860 MPa Low Relaxation Strand:

P_{jack}	=	31300 kN
Anchor Set	=	10 mm
Total Number of Ducts	=	8

Distribution of prestress force (P_{jack}) between ducts shall not exceed the ratio of 3:2.

Maximum final force variation between ducts shall not exceed 3200 kN.

Concrete: f_c' = 35 MPa at 28 days

f_{ci}' = 25 MPa at time of stressing

Contractor shall submit elongation calculations based on initial stress at

[X] = 0.929 times jacking stress.

One end stressing shall be performed from either end.

23. References

1. *Metric Guide for Federal Construction*, First Edition, July 1993.
2. *Interim Selected Metric Values for Geometric Design*, R. P. Weaver, Interim Chief Deputy Director, Caltrans, 12/17/93.
3. *Interim Drafting Standards for Metric Plans*, R. P. Weaver, Interim Chief Deputy Director, Caltrans, 12/15/93.
4. *Initiation of Metric Plans, Specifications and Estimates*, Memo from R. P. Weaver, Interim Chief Deputy Director, Caltrans, 12/17/93.
5. *Getting Into Metrics, A Metric Primer*, Caltrans Office of Project Planning and Design, December 1993.
6. Metric Video.
7. *Steel Bridge Metrication Issues and Discussion,* The National Steel Bridge Alliance (A division of American Institute of Steel Construction, Inc.), November 1995.
8. *Guide to Metric Conversion,* American Association of State Highway and Transportation Officials.